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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Applicant:	§	
POLAT et al	§	
Serial No.: 09/711,354	§	
Filed: November 9, 2000	§	Group Art Unit: 2621
For: Methods and Systems for Improving A User's Visual Perception Over A Communications Network	§	Attorney Docket: **26594** Previously 251/255
Examiner: Shefali D. Patel	§	

Commissioner for Patents
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CLAIM OF PRIORITY RIGHTS

Sir:

Applicant hereby claims the priority date of Israel Patent Application No. 133758 filed December 27, 1999 and encloses herewith a certified copy of that Israel Patent Application to support the claim for its priority date.

Respectfully submitted,

Sol Sheinbein
Registration No. 25,457

Date: March 30, 2004

CERTIFIED COPY OF PRIORITY DOCUMENT

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PATENTS LAW, 5727-1967

בקשה לפטנט
Application for Patent

C:36136

אני, (שם המבקש, מענו -- ולגבי גוף מאוגד -- מקום התאגדותו)
I (Name and address of applicant, and, in case of body corporate-place of incorporation)

NEUROVISION INC.
c/o SCIENCE FOR SIGHT LTD.
14 Ahad Haam Street
P.O.B. 435
Rehovot 76103

בעל אמצאה מכח הדין ששמה הוא
Owner, by virtue of By Law of an invention, the title of which is:

(בעברית) (Hebrew) שיטה ומתקן לשיפור ראייה

(באנגלית) (English) METHOD AND APPARATUS FOR IMPROVING VISION

hereby apply for a patent to be granted to me in respect thereof מבקש בזאת כי ינתן לי עליה פטנט

*בקשה חלוקה - Application for Division	*בקשת פטנט מוסף - Application for Patent of Addition	*דרישה דין קדימה Priority Claim		
מבקשת פטנט from Application	*לבקשה/לפטנט to Patent/Appl.	מספר/סימן Number/Mark	תאריך Date	מדינת האיגוד Convention Country
No. ______ מס. dated ______ מיום	No. ______ מס. dated ______ מיום			
*יפוי כח: כללי/מיוחד - רצוף בזה / עוד יוגש P.O.A.: general / individual - attached / to be filed later - filed in case ______ הוגש בענין				
המען למסירת הודעות ומסמכים בישראל Address for Service in Israel Sanford T. Colb & Co. P.O.B. 2273 Rehovot 76122				
חתימת המבקש Signature of Applicant For the Applicant, Sanford T. Colb & Co. C:36136		היום 27 בחודש December שנת 1999 This 27 of December of the year 1999		
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שיטה ומתקן לשיפור ראייה

METHOD AND APPARATUS FOR IMPROVING VISION

NEUROVISION INC.
c/o SCIENCE FOR SIGHT LTD.
C: 36136

36136uri.doc 27-Dec-99

METHOD AND APPARATUS FOR IMPROVING VISION

FIELD OF THE INVENTION

The present invention relates generally to apparatus and methods for improving vision, such as for treatment of amblyopia.

BACKGROUND OF THE INVENTION

Amblyopia (lazy eye) is a defect in the visual acuity of an eye that is anatomically and functionally normal, which persists after refractive errors in the eye were corrected. The cause of amblyopia is generally believed to be an abnormality that occurred during a critical period in childhood and prevented the visual system from developing normally. Normally two identical images are transferred from both eyes to the brain, which fuses the two images into a composite, single image. However, sometimes the image arriving from one eye is significantly different than that arriving from the other eye. This can be caused by a variety of factors, such as the eyes not being parallel (strabismus or squint), one eye being more shortsighted than the other, or conditions that create abnormal images in one or both eyes.

Amblyopia in children is usually treated by occluding the non-amblyopic eye. The idea behind this method is to "force" the amblyopic eye to "strengthen", i.e., increase in visual acuity. Occlusion of the dominant eye is a long established method and produces good results in many cases. However, it has many drawbacks. The method is only useful until the age of about nine, and beyond that age the method is basically useless. Even for children below the age of about nine, there are several disadvantages, such as impaired visual function, social and emotional problems due to wearing an unsightly patch over one eye, and sometimes skin irritation associated with the patch.

Other prior art methods include optical penalization, in which lenses are used to blur, rather than occlude, the vision of the non-amblyopic eye. Cycloplegic drugs have also been used to blur the vision of the non-amblyopic eye. However, these methods are not preferred and have limited success for various reasons. For example, blurring vision is taxing and annoying to the patient and drugs must be administered with caution.

US Patent 5,206,671 to Eydelman et al., the disclosure of which is incorporated herein by reference, describes a method for testing and treating amblyopia. Eydelman et al. provides an interactive visual game that presents to the patient a visual task. The visual game employs images scaled to the threshold visual parameters of the patient, and presents a nonvisual, i.e., auditory reward to the patient for successful completion of the task. The

auditory reward is a sound pleasing to the patient, such as a musical selection or song chosen by the patient.

One example of an interactive visual game involves displaying a series of capital letter E's on a computer screen and asking the patient to select a key on the keyboard corresponding to the correct orientation of the letters. If the patient correctly senses the orientation of the letters, he/she is rewarded with a pleasing tune. Another example involves presenting to the patient a plurality of cartoon characters on the computer screen, wherein all of the characters have some common trait or are identical except for one character which is different. The patient is asked to select which character does not belong to the rest of the group of characters. Yet another example involves finding matching characters. In each case there is an auditory reward for a correct answer. The games are gradually increased in difficulty in order to build up the acuity of the amblyopic eye.

However, Eydelman et al. does not seem to be successful for treating amblyopia in adults or children older than the critical age of about nine years old. Indeed there is no known method in the prior art for treating amblyopia in adults or children older than the critical age of about nine years old with consistent success.

SUMMARY OF THE INVENTION

The present invention seeks to provide novel apparatus and methods for not only treating amblyopia, but for improving vision of any observer, no matter whether the observer has normal or abnormal vision. The invention can be used to improve vision of observers suffering from problems such as dyslexia. Even persons with anatomical or functional problems, such as macular degeneration, can improve what vision they have with the methods and apparatus of the present invention.

The invention uses novel, repetitive learning procedures to improve the visual acuity of the eye. The methods of the invention have been successfully tested in clinical trials on 16 adults, most of them amblyopic. Visual acuity improved by at least 60% in all of the adults. Some of the patients showed a dramatic improvement of more than 4 times their initial visual acuity. In seven individuals, the vision was improved to normal or near normal vision. Moreover, in three normal subjects that served as a control, vision was improved from 66% to double their initial visual acuity (from 6/6 vision to 6/3 vision!). The invention is also applicable for treatment of children.

The invention makes use of research performed by the inventor in the nature of visual responses. As will be explained hereinbelow, the invention significantly improves upon

previously reported attempts of repetitive procedures to increase visual acuity in amblyopes. An overview of the research can be found in Uri Polat, "Functional architecture of long-range perceptual interactions", *Spatial Vision*, 12:143-162 (1999). This research tends to support a theory that connects amblyopia to abnormal spatial interactions, as will be explained hereinbelow. It is to be stressed, however, that although the present invention makes use of this theory, nevertheless the invention is *not* bound by the theory. The invention successfully works (as witnessed by the abovementioned successful trials) even if the theory is not fully understood and even if it turns out that the theory is flawed. Indeed not all researchers agree with all that is postulated in the abovementioned article by Polat. (See, for example, Dennis Levi et al., "Rapid Communication", Vision Res., 38:775-781 (1998), particularly page 779, third paragraph of the discussion.) Thus, even in light of the article by Polat, the methods and apparatus of the present invention, are not at all obvious and are actually contrary to the teachings of some researchers The successful results of the trials that used the methods and apparatus of the present invention are therefore significant and surprising in light of the prior art.

As stated in the foregoing paragraph, the theoretical explanation is now presented only for purposes of better understanding the disclosure of the invention, but not as the binding basis of the invention:

The neuronal visual system of the eye and brain can detect small local luminance differences, i.e., contrasts, and group them into objects or features. According to the Gestalt theory of perception, the visual system groups the features together on the basis of similarity of orientation of shapes, proximity, smoothness (i.e., collinearity), closure, common region and connectivity. According to the classical understanding of the organization of the visual cortex, neurons mediate visual information from the retina to the visual cortex through a few successive stages, each stage elaborating on the feature selectivity developed at the previous stage. In this classical understanding, the basis of visual analysis resides in receptor fields known as classical receptive fields (CRFs). The CRF comprises simple cells that have been tuned selectively for location, orientation and spatial frequency.

Research indicates that visual responses of the visual system depend upon input from both the center and an area surrounding the center of the CFR. In other words, the visual system groups features together by means of *lateral interactions* between the center and surrounding area of the CFR. In the abovementioned article by Polat, it is postulated that normal lateral interactions produce a selective neuronal network of *excitatory* (amplifying,

facilitating) and *inhibitory* (suppressing) interactions that are capable of controlling the perceptual grouping. If the context of a visual stimulus satisfies the Gestalt rules of grouping, the interaction is excitatory and the neuronal network enhances (i.e., facilitates) the perception of the stimulus. If the context of a visual stimulus does not satisfy the Gestalt rules of grouping, the interaction is inhibitory and the neuronal network suppresses the perception of the stimulus.

One type of a visual stimulus that can solicit a visual neuronal response is a grating patch. Gratings patches, also referred to as Gabor patches, are a plurality of white, gray and/or black areas, characterized by a particular contrast, spacing, shape and length. In Uri Polat and Dov Sagi, "Plasticity of Spatial Interactions in Early Vision", Maturational Windows and Adult Cortical Plasticity, Eds. B. Julesz & I. Kovacs, SFI Studies in the Sciences of Complexity, Vol. XXIII, Addison-Wesley, 1995, pp. 111-125, observers were trained to detect a central Gabor target flanked by two high contrast Gabor flanker patches. Polat and Sagi found that the contrast threshold for a small foveally viewed Gabor patch can be enhanced or suppressed by the lateral placement of other Gabor patches of similar orientation and spatial frequency. The separation of the target and flankers, the relative orientation of the flankers and the global configuration of the three Gabor patches (see Fig. 1) determine whether there is excitatory or inhibitory interaction. Collinear, co-oriented targets separated by several wavelengths of the spatial frequency of the Gabor patches were found to produce maximal facilitation. The facilitation was found to be independent of the target and mask orientations and locations (meridian).

Other articles of note which discuss the facilitation of the visual response associated with Gabor patches include Uri Polat et al., "Collinear stimuli regulate visual responses depending on cell's contrast threshold", Nature, 391:580-584 (5 February 1998); Uri Polat and Dov Sagi, "Spatial interactions in human vision: From near to far via experience-dependent cascades of connections", Proc. Natl. Acad. Sci. USA, 91:1206-1209 (February 1994); and Uri Polat and Dov Sagi, "The Architecture of Perceptual Spatial Interactions", Vision Res., 34:73-78 (1994).

In the abovementioned article of Uri Polat in *Spatial Vision*, collinear facilitatory interactions were postulated to be building blocks in major grouping tasks such as contour integration. Contours made up of a contiguous series collinear elongated filters can be easily discerned even if embedded within a randomly oriented background of Gabor elements

or "background noise". In other words, these contours have a high signal-to-noise ratio, i.e., they can evoke an excitatory interaction even in the presence of background noise.

Amblyopic observers suffer from reduced visual acuity, reduced sensitivity for spatial contrast, reduced vernier acuity, spatial distortion, abnormal spatial interactions and impaired contour detection. Abnormal contrast sensitivity functions occur in most amblyopic eyes, and mainly at high spatial frequencies, with little or no loss of contrast sensitivity at low spatial frequencies. In other words, the contrast threshold in amblyopic eyes is usually higher than that of normal eyes, probably due to a weak signal or increased intrinsic noise. Amblyopes may have abnormally high degrees of intrinsic noise, which may form the basis of their abnormal contrast sensitivity function.

Abnormal spatial interactions have been observed in amblyopic observers. See Uri Polat et al., "Abnormal Long-Range Spatial Interactions in Amblyopia", Vision Res., 37: 737-744 (1997). In psychophysical and visual evoke potential (VEP) experiments, amblyopes exhibited several deviations from normal patterns. Their facilitation for collinear configurations was either markedly lower than normal or was replaced by inhibition. Other studies have shown that amblyopic observers also failed in the task of contour integration.

When observers perform a visual (or any other sensory) discrimination task, their performance often improves with practice, even with simple tasks. (Indeed this is also the principle underlying Eydelman et al. mentioned above in the background of the invention.) Strong and significant improvement of vernier acuity in human adults with naturally occurring amblyopia has been achieved with repetitive learning procedures, as reported in Dennis M. Levi and Uri Polat, "Neural plasticity in adults with amblyopia", Proc. Natl. Acad. Sci. USA, 93:6830-6834 (June 1996) and in Dennis M. Levi, Uri Polat and Ying-Sheng Hu, "Improvement in Vernier Acuity in Adults with Amblyopia; Practice Makes Better", Investigative Ophthalmology & Visual Science, 38:1493-1510 (July 1997). The stimuli in these procedures consisted of short, dark line segments presented on a background with a mean luminance of 100 cd/m^2. The Vernier stimulus consisted of two abutting, dark lines with a Vernier offset between the two lines. The lines had a Weber contrast of 80%. The line detection stimulus was one of these Vernier lines, whose contrast was varied in order to measure the line contrast threshold.

However, since vernier acuity is just one of the deficiencies present in amblyopes, it is readily understood that further methods must be devised for the full, proper treatment of amblyopia. **This is one of the goals of the present invention.** More importantly,

as will be discussed further hereinbelow, the invention is applicable for **improving vision of any observer** as well. Surprisingly, the invention has improved normal vision of observers to above normal vision.

In the present invention, a number of visual tasks are used to determine the degree of amblyopia of the patient, i.e., the level of performance of the visual system of the patient. This level is compared to the performance of observers with normal vision. The data collected about the patient's performance is analyzed to determine the types of neural defects, such as reduced visual acuity, reduced sensitivity for spatial contrast, reduced vernier acuity, spatial distortion, abnormal spatial interactions, impaired contour detection, abnormal contrast sensitivity functions and abnormally high degrees of intrinsic noise. (Again, it is to be stressed that the prior art of Polat has only dealt with vernier acuity but none of the other defects .)

In accordance with the analysis of the neural defects, a computerized system establishes an initial target arrangement of visual images, preferably Gabor patches, characterized by a certain contrast and distance between images. The images are presented to the patient on a screen of a monitor. The patient has to perform a visual task of indicating whether he/she sees a target arrangement, such indication being made on the screen, for example, by means of a mouse.

Each session is designed to train directly and selectively those functions in the brain that were diagnosed to be malfunctioning. At each session, preferably daily, an algorithm analyzes the patient's responses and accordingly adjusts the level of visual difficulty to the range most effective for further improvement. Between daily sessions, the progress of the patient is measured and taken into account by the algorithm for the next therapeutic session. Thus, for each patient an individual training schedule is designed based on the initial state of visual performance, severity of dysfunction and progress in therapeutic training.

There is thus provided in accordance with a preferred embodiment of the present invention a method for improving vision, including establishing an initial arrangement of visual images that are characterized by a parameter including at least one of a contrast, a spatial frequency, a distance between the images, and a global orientation of the images, displaying the images to a patient on a display screen, the patient having any visual acuity, normal or abnormal, having the patient perform a visual task associated with the images, analyzing the patient's performance of the visual task, modifying the parameter associated with the visual images so as to adjust a level of difficulty of the visual task, in accordance with analysis of the patient's performance of the visual task, repeatedly displaying modified visual

images and having the patient perform a visual task associated with the modified images, until a desired level of improvement in the visual acuity of the patient has been reached.

In accordance with a preferred embodiment of the present invention the method further includes, before the step of establishing an initial arrangement of visual images, determining a level of performance of a visual system of the patient, the visual system having a defect including at least one of reduced sensitivity for spatial contrast, spatial distortion, abnormal spatial interactions, impaired contour detection, abnormal contrast sensitivity functions and abnormally high degrees of intrinsic noise, making comparison of the level of performance to that of a normal observer, and analyzing the comparison to determine types of neural defects.

Further in accordance with a preferred embodiment of the present invention the visual images include Gabor patches.

Still further in accordance with a preferred embodiment of the present invention the visual images include a central Gabor patch flanked by two other Gabor patches of similar orientation and spatial frequency placed laterally of the central Gabor patch.

In accordance with a preferred embodiment of the present invention the Gabor patches are collinear and co-oriented.

Further in accordance with a preferred embodiment of the present invention the Gabor patches are separated from each other in a range of about 0-12 wavelengths of the spatial frequency of the patches.

Still further in accordance with a preferred embodiment of the present invention the Gabor patches are arranged to form a contour.

In accordance with a preferred embodiment of the present invention the visual task includes the patient indicating whether the patient sees the arrangement of images by performing a function on the display screen.

Further in accordance with a preferred embodiment of the present invention the step of modifying the parameter further includes modifying at least one of color, shape and size of the visual images.

There is also provided in accordance with a preferred embodiment of the present invention apparatus for improving vision, including a plurality of visual images that are characterized by a parameter including at least one of a contrast, a spatial frequency, a distance between the images, and a global orientation of the images, a processor for generating the images, a display screen in communication with the processor for presenting the images to a

patient, an input device in communication with the display screen for providing responses to the images, and a data collector in communication with the processor for collecting data related to a performance of a visual system of a patient, the patient having any visual acuity, normal or abnormal, wherein the processor establishes an arrangement of the visual images and creates a visual task for the patient to perform, the visual task being displayed on the display screen, wherein the data collector repeatedly collects data related to the patient's performance of the visual task, the processor repeatedly processing and analyzing the data and modifying the parameter associated with the visual images so as to adjust a level of difficulty of the visual task, in accordance with analysis of the patient's performance of the visual task, until a desired level of improvement in the visual acuity of the patient has been reached.

There is also provided in accordance with a preferred embodiment of the present invention apparatus for improving vision, including a plurality of visual images, a server of a computer network including a processor for generating the images, a display screen in communication with the processor for presenting the images to a patient, an input device in communication with the display screen for providing responses to the images, and a data collector in communication with the processor for collecting data related to a performance of a visual system of a patient, the patient having any visual acuity, normal or abnormal, wherein the processor establishes an arrangement of the visual images and creates a visual task for the patient to perform, the visual task being displayed on the display screen, wherein the data collector repeatedly collects data related to the patient's performance of the visual task, the processor repeatedly processing and analyzing the data and modifying the parameter associated with the visual images so as to adjust a level of difficulty of the visual task, in accordance with analysis of the patient's performance of the visual task, until a desired level of improvement in the visual acuity of the patient has been reached.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description, taken in conjunction with the drawings in which:

Fig. 1 is a simplified illustration of local and global orientations of three Gabor patches, which are known in the art;

Fig. 2A is a simplified illustration of an initial set of visual images that are presented to a patient in accordance with a preferred embodiment of the present invention;

Fig. 2B is a simplified illustration of a different set of visual images that are presented to a patient after adjusting certain parameters, such as contrast and distance between

images, based on a patient's response to the initial set of visual images, in accordance with a preferred embodiment of the present invention;

Fig. 3 is a simplified illustration of apparatus for improving vision, in accordance with a preferred embodiment of the present invention; and

Fig. 4 is a simplified flow chart of a method for improving vision, in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Reference is now made to Fig. 3 which illustrates apparatus 10 for treatment of amblyopia constructed and operative in accordance with a preferred embodiment of the present invention.

Apparatus 10 includes a processor 12 for generating visual images 11, shown in Figs. 2A and 2B, are described hereinbelow. A display screen 14 is in communication with processor 12 for presenting the images 11 to a patient (not shown). An input device, such as a mouse 16 or keyboard 18, is in communication with display screen 14 for providing responses of the patient to the images 11. The patient performs a visual task associated with images 11, as described hereinbelow. A data collector 20 is in communication with processor 12 for collecting data related to a performance of a visual system of the patient. This data can be indicative of a defect of the visual system and is related to such factors as reduced sensitivity for spatial contrast, spatial distortion, abnormal spatial interactions, impaired contour detection, abnormal contrast sensitivity functions and abnormally high degrees of intrinsic noise. This is in contrast with the prior art that only dealt with vernier acuity.

In accordance with another preferred embodiment of the present invention, processor 12 is located remotely from display screen 14. In such an embodiment, processor 12 resides in a server 40 of a computer network, such as the Internet. A user can enter a website on the Internet and request a therapy session. Processor 12 generates a set of visual images 11 and sends them via the Internet to display screen 14, whereupon the user can perform a required visual task, as is described hereinbelow. Data collector 20 collects data related to a performance of the visual system of the user. The data is sent to processor 12 via the Internet. Processor 12 analyzes the patient's performance, and modifies a parameter associated with the visual images (e.g., contrast, distance between images) so as to adjust a level of difficulty of the visual task, in accordance with the analysis of the patient's performance of the visual task, as is described hereinbelow. Such an embodiment with a remote processor, enables carrying out the invention at any convenient site, such as in the home, school or office, for example.

Reference is now made to Figs. 2A and 2B which illustrate examples of visual images 11. The visual images 11 preferably include a central Gabor patch 22 flanked by two other Gabor patches 24 and 26 of similar orientation and spatial frequency placed laterally of the central Gabor patch 22.

The following values are presented as just one illustrative example of parameters associated with the Gabor patches, but it is appreciated that the invention is not limited to these values: The central Gabor patch 22 preferably coincides with a fixation point of an observer (the central patch 22 being fovean), sitting a distance of about 1.0-2.5 meters from display screen 14. The Gaussian envelope size ($\sigma = \lambda = 0.15°$) may be such that at least one cycle is within a range of $\pm\sigma$ from the Gaussian center. The carrier spatial frequency of the Gabor patches may be 6.6 cycles per degree ($\lambda = 0.15°$) and mask contrast may be 40%. In Figs. 2A and 2B, the visual images have a local and global vertical orientation (see Fig. 1 for definitions of local and global orientations). In Fig. 2A, the distance d between the central Gabor patch 22 and the flanking patches 24 and 26 may be 1.5λ. The initial contrasts of the patches may be in the range of 8-50%, for example. In short, each visual image is characterized by a parameter comprising at least one of a contrast, a spatial frequency, a distance between the images, and local and global orientation, and possibly other parameters as well.

In accordance with a preferred embodiment of the present invention the Gabor patches are collinear and co-oriented. The Gabor patches may be separated from each other in a range of about 0-12 wavelengths of the spatial frequency of the patches. As seen in Figs. 2A and 2B, the Gabor patches may be arranged to form a contour (in Figs. 2A and 2B, the contour is generally a straight line, but curvilinear and other contours are also possible).

It is to be emphasized that the invention is not restricted to Gabor patches, but rather any kind of visual image, such as straight lines or curved lines or other shapes, for example. The particular visual image used may be selected depending upon the needs and treatment plan of the patient.

Reference is now made to Fig. 4 which illustrates, in flow-chart form, a method for improving vision, in accordance with a preferred embodiment of the present invention.

First, in the case of an amblyopic patient, the patient is examined and tested, such as by means of the abovementioned Gabor patches, to determine a level of performance of the visual system of the patient. As stated above, the visual system of amblyopes may have a neural defect related to reduced sensitivity for spatial contrast, spatial distortion, abnormal spatial interactions, impaired contour detection, abnormal contrast sensitivity functions and/or

abnormally high degrees of intrinsic noise. Data collector 20 may be used to collect the data about the visual system for eventual processing by processor 12.

The level of performance is compared to that of a normal observer. Such comparison is preferably performed by processor 12, with data related to that of a normal observer being stored in processor 12, for example. Processor 12 analyzes the comparison to determine the types of neural defects present in the visual system of the patient.

Processor 12 preferably establishes an initial arrangement of visual images, which are displayed on display screen 14. The arrangement is characterized by contrast of the visual images and distance therebetween, for example, as mentioned above. The contrast may be constant or changing. (As mentioned previously, the invention may be carried out for any observer, not necessarily amblyopes. In the case of a person with normal vision or myopic or hyperopic vision, for example, the method may commence with processor 12 establishing an initial arrangement of visual images, and the previous steps may be omitted.)

The patient then performs a visual task associated with the images. For example, the patient may indicate whether he/she sees the arrangement of images by performing a function on display screen 14, such as by indicating the perceived contour formed by the images with the mouse 16. A correct response signals processor 12 to display the next set of images or to change contrast, distance or some other parameter, such as color, shape or size. An incorrect response may trigger a buzzer or some other sound. (This is in contrast to Eydelman et al. wherein a correct response is rewarded with an auditory signal.)

After a predetermined number of visual tasks have been performed, processor 12 analyzes the patient's performance. Processor 12 modifies the parameter associated with the visual images (e.g., contrast, distance between images) so as to adjust a level of difficulty of the visual task, in accordance with the analysis of the patient's performance of the visual task. For example, after the initial set of images shown in Fig. 2A, processor 12 may modify the images to that shown in Fig. 2B, wherein the contrast and distance between images have been modified. The patient then repeats the visual tasks at the next therapeutic session. The sessions are repeated until a desired level of improvement in visual acuity for any observer, amblyope, myope, hyperope or normal, or in the neural defect (in the case of amblyopes) has been reached.

It is noted that none of the prior art can improve visual acuity of *any* observer, amblyope, myope, hyperope or normal. It is further noted that although some of the prior art has improved vernier acuity (Dennis M. Levi and Uri Polat, "Neural plasticity in adults with

amblyopia", Proc. Natl. Acad. Sci. USA, 93:6830-6834 (June 1996); and Dennis M. Levi, Uri Polat and Ying-Sheng Hu, "Improvement in Vernier Acuity in Adults with Amblyopia; Practice Makes Better", Investigative Ophthalmology & Visual Science, 38:1493-1510 (July 1997), cited above), none of the prior art has improved visual acuity on the whole. It is also noted that Eydelman et al. only modified local orientation of objects, but did not modify global orientation, contrast, spatial frequency, or distance between images.

As stated above, the methods of the invention have been successfully tested in clinical trials on 16 adults, and have surprisingly provided significant results. Visual acuity improved by at least 60% in all of the adults. Some of the patients showed a dramatic improvement of more than 4 times their initial visual acuity. In seven individuals, the vision was improved to normal or near normal vision. Moreover, in three normal subjects that served as a control, vision was improved from 66% to double their initial visual acuity.

It will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention includes both combinations and subcombinations of the features described hereinabove as well as modifications and variations thereof which would occur to a person of skill in the art upon reading the foregoing description and which are not in the prior art.

CLAIMS

What is claimed is:

1. A method for improving vision, comprising:

establishing an initial arrangement of visual images that are characterized by a parameter comprising at least one of a contrast, a spatial frequency, a distance between said images, and a global orientation of said images;

displaying said images to a patient on a display screen, said patient having any visual acuity, normal or abnormal;

having the patient perform a visual task associated with said images;

analyzing the patient's performance of said visual task;

modifying said parameter associated with said visual images so as to adjust a level of difficulty of said visual task, in accordance with analysis of the patient's performance of said visual task;

repeatedly displaying modified visual images and having the patient perform a visual task associated with said modified images, until a desired level of improvement in the visual acuity of the patient has been reached.

2. The method according to claim 1 and further comprising, before the step of establishing an initial arrangement of visual images:

determining a level of performance of a visual system of the patient, said visual system having a defect comprising at least one of reduced sensitivity for spatial contrast, spatial distortion, abnormal spatial interactions, impaired contour detection, abnormal contrast sensitivity functions and abnormally high degrees of intrinsic noise;

making comparison of the level of performance to that of a normal observer;

and analyzing the comparison to determine types of neural defects.

3. The method according to claim 1 wherein said visual images comprise Gabor patches.

4. The method according to claim 1 wherein said visual images comprise a central Gabor patch flanked by two other Gabor patches of similar orientation and spatial frequency placed laterally of the central Gabor patch.

5. The method according to claim 4 wherein said Gabor patches are collinear and co-oriented.

6. The method according to claim 4 wherein said Gabor patches are separated from each other in a range of about 0-12 wavelengths of the spatial frequency of said patches.

7. The method according to claim 4 wherein said Gabor patches are arranged to form a contour.

8. The method according to claim 1 wherein said visual task comprises said patient indicating whether said patient sees said arrangement of images by performing a function on said display screen.

9. The method according to claim 1 wherein the step of modifying said parameter further comprises modifying at least one of color, shape and size of said visual images.

10. Apparatus for improving vision, comprising:

a plurality of visual images that are characterized by a parameter comprising at least one of a contrast, a spatial frequency, a distance between said images, and a global orientation of said images;

a processor for generating said images;

a display screen in communication with said processor for presenting said images to a patient;

an input device in communication with said display screen for providing responses to said images; and

a data collector in communication with said processor for collecting data related to a performance of a visual system of a patient, the patient having any visual acuity, normal or abnormal;

wherein said processor establishes an arrangement of said visual images and creates a visual task for the patient to perform, said visual task being displayed on said display screen, wherein said data collector repeatedly collects data related to the patient's performance of said visual task, said processor repeatedly processing and analyzing said data and modifying said parameter associated with said visual images so as to adjust a level of difficulty of said visual task, in accordance with analysis of the patient's performance of said visual task, until a desired level of improvement in the visual acuity of the patient has been reached.

11. Apparatus for improving vision, comprising:

a plurality of visual images;

a server of a computer network comprising a processor for generating said images;

a display screen in communication with said processor for presenting said images to a patient;

an input device in communication with said display screen for providing responses to said images; and

a data collector in communication with said processor for collecting data related to a performance of a visual system of a patient, the patient having any visual acuity, normal or abnormal;

wherein said processor establishes an arrangement of said visual images and creates a visual task for the patient to perform, said visual task being displayed on said display screen, wherein said data collector repeatedly collects data related to the patient's performance of said visual task, said processor repeatedly processing and analyzing said data and modifying said parameter associated with said visual images so as to adjust a level of difficulty of said visual task, in accordance with analysis of the patient's performance of said visual task, until a desired level of improvement in the visual acuity of the patient has been reached.

12. Apparatus according to claim 10 or claim 11 wherein said data collector collects data indicative of a defect of the visual system comprising at least one of reduced sensitivity for spatial contrast, spatial distortion, abnormal spatial interactions, impaired contour detection, abnormal contrast sensitivity functions and abnormally high degrees of intrinsic noise.

13. Apparatus according to claim 12 wherein said processor processes said data to analyze said defect.

14. Apparatus according to claim 10 or claim 11 wherein said visual images comprise Gabor patches.

15. Apparatus according to claim 10 or claim 11 wherein said visual images comprise a central Gabor patch flanked by two other Gabor patches of similar orientation and spatial frequency placed laterally of the central Gabor patch.

16. Apparatus according to claim 15 wherein said Gabor patches are collinear and co-oriented.

17. Apparatus according to claim 15 wherein said Gabor patches are separated from each other in a range of about 0-12 wavelengths of the spatial frequency of said patches.

18. Apparatus according to claim 15 wherein said Gabor patches are arranged to form a contour.

19. The method according to any of claims 1-8 and substantially as described hereinabove.

20. Apparatus according to any of claims 10-18 and substantially as described hereinabove.

For the Applicant,

Sanford T. Colb & Co.
Advocates & Patent Attorneys
C:36136

(PRIOR ART) FIG. 1

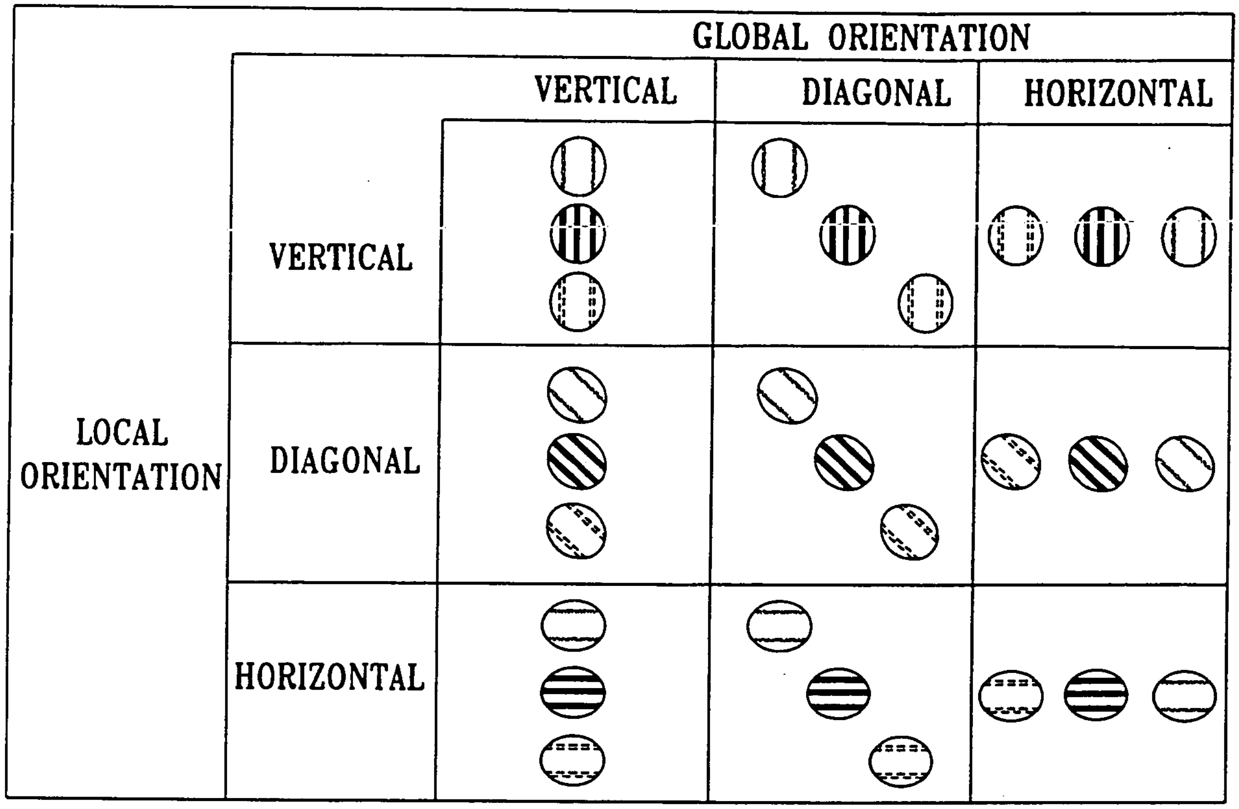


FIG. 2A

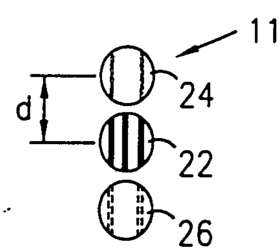


FIG. 2B

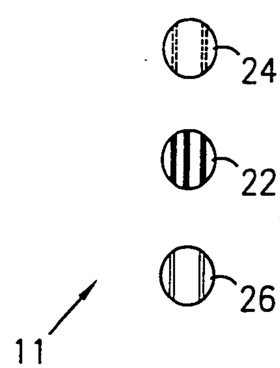
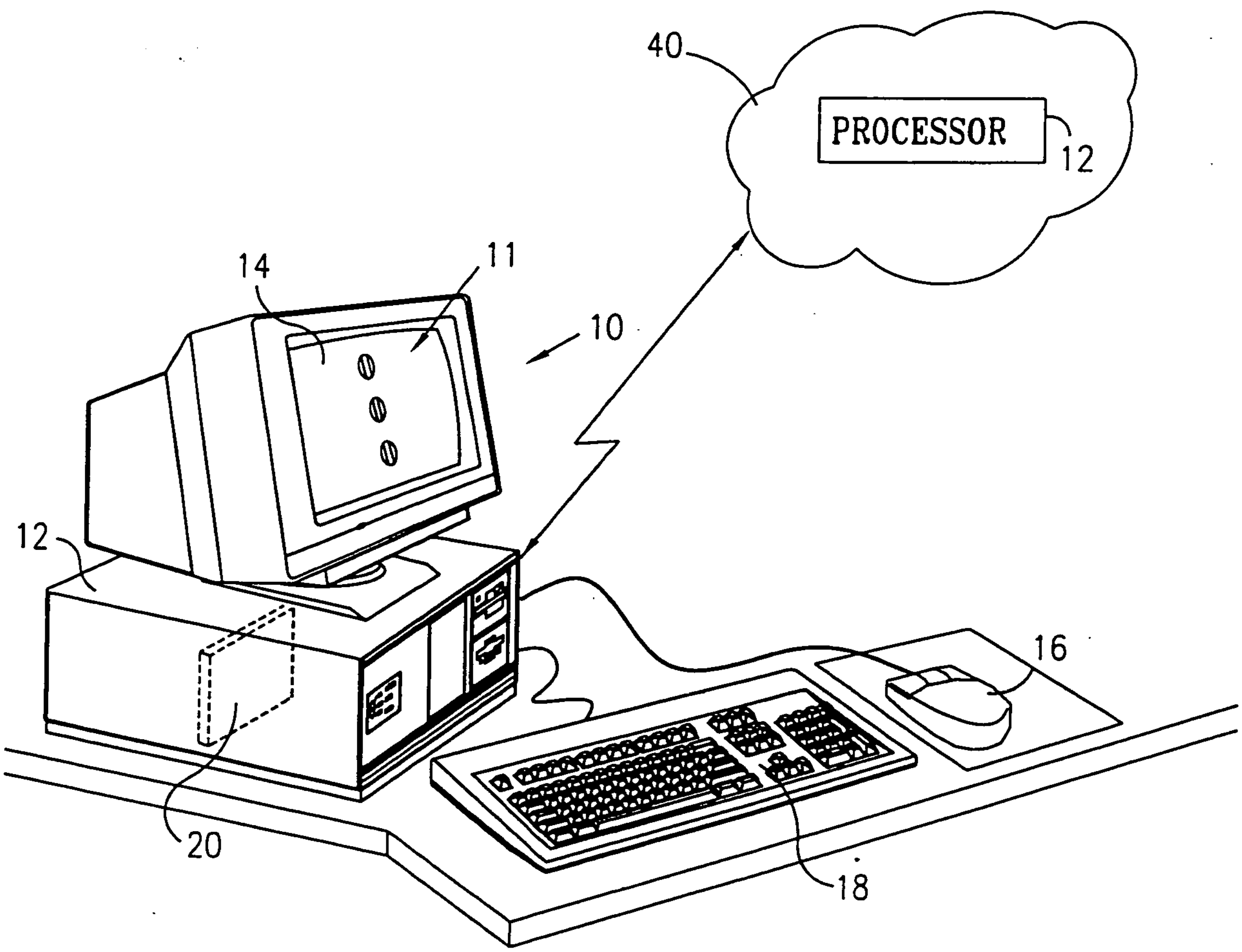


FIG. 3



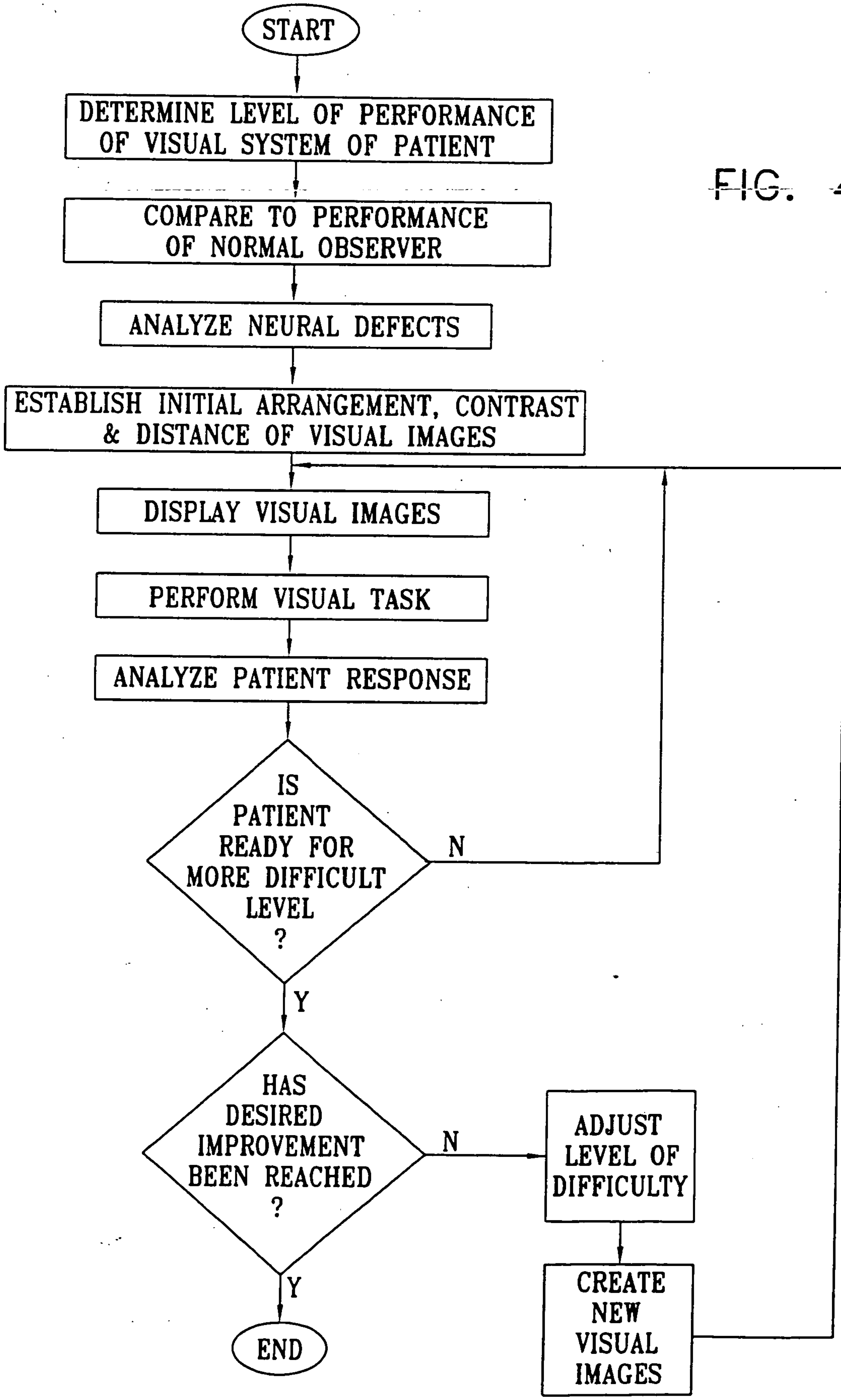

START
DETERMINE LEVEL OF PERFORMANCE OF VISUAL SYSTEM OF PATIENT
COMPARE TO PERFORMANCE OF NORMAL OBSERVER
ANALYZE NEURAL DEFECTS
ESTABLISH INITIAL ARRANGEMENT, CONTRAST & DISTANCE OF VISUAL IMAGES
DISPLAY VISUAL IMAGES
PERFORM VISUAL TASK
ANALYZE PATIENT RESPONSE
IS PATIENT READY FOR MORE DIFFICULT LEVEL ?
N
Y
HAS DESIRED IMPROVEMENT BEEN REACHED ?
N
ADJUST LEVEL OF DIFFICULTY
CREATE NEW VISUAL IMAGES
Y
END

FIG. 4